Gluon Evolution in High Density QCD[*]

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One of the most important problems in Ultra-relativistic heavy ion collisions is understanding the initial conditions of the collision which will dictate the outcome. With major heavy ion experiments planned for RHIC and LHC, it is imperative to gain a deep theoretical understanding of the initial conditions. To this effect, one needs to have a better determination of initial parton distributions in the colliding nuclei.

Nuclear parton distributions are needed in order to compute nuclear cross sections. Typically, one takes the known hadronic parton distributions and scales them with the nucleon number A to get the nuclear parton distributions. However, it is experimentally known that nuclear parton distributions are depleted as compared to what one expects from a simple scaling. This depletion is refered to as shadowing and depends strongly on the energies of the colliding nuclei and gets bigger and bigger as one goes to higher and higher energies (small x). At high energies, gluons are the most abundant partons in a hadron or nucleus and therfore it is very important to understand the effect of shadowing on the nuclear gluon distribution.

In a frame where the nucleus is moving fast, shadowing of gluon distribution function is described by including non-linear terms in the gluon evolution equation due to gluon recombination effects. To do this, we start with the following action in QCD

$$\begin{aligned} S &= -\frac{1}{4}\int d^4x G_a^{\mu\nu} G^a_{\mu\nu} + i\int d^2x_\perp F[\rho^a(x_\perp)] \\ &+ \frac{i}{N_c}\int d^2x_\perp dx^- \delta(x^-) \mathrm{tr}\rho(x_\perp) W_{-\infty,\infty}[A^-] \end{aligned}$$

By integarting out the high momentum modes of the gluon fields, one can derive an effective action for the soft modes of the gluon fields which in turn makes derivation of a general evolution equation which takes recombination effects at high energies into account possible [1].

By considering the double log kinematic region, one can derive a closed form evolution equation for gluons which incorporates recombination effects to all orders in the gluon dsensity. It is [2]

$$\frac{\partial^2}{\partial y \partial \xi}\, xG(x,Q,b_\perp) = \frac{N_c(N_c-1)}{2}\, Q^2 \left[1 - \frac{1}{\kappa} Exp(\frac{1}{\kappa}) E_1(\frac{1}{\kappa})\right]$$

where

$$\kappa = \frac{2\alpha_s}{\pi(N_c-1)Q^2} xG(x,Q,b_\perp)$$

and $\mathrm{E}_1(x)$ is the exponential integral function defined as

$$\mathrm{E}_1(x) = \int_0^\infty dt\, \frac{e^{-(1+t)x}}{1+t}, \quad x > 0$$

It can be shown that this equation reduces to the standard QCD evolution equations in the low density limit and leads to unitarization of gluon density in hadrons and shadowing of gluon distribution in nuclei. In order to quantitatively study shadowing of gluon distribution in nuclei, one needs to solve the above equation. Work in this direction is in progress [3].

[1] J. Jalilian-Marian et al., Phys. Rev. D59 (1999) 014015; Phys. Rev. D59 (1999) 014014, Nucl. Phys. B504 (1997) 415.

[2] J. Jalilian-Marian et al., Phys. Rev. D59 (1999) 034007.

[3] J. Jalilian-Marian and X.N. Wang, work in progress.

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